



US009148797B2

(12) **United States Patent**
Thomson

(10) **Patent No.:** **US 9,148,797 B2**
(45) **Date of Patent:** ***Sep. 29, 2015**

(54) **TROUBLESHOOTING CLIENT ROAMING**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.
This patent is subject to a terminal disclaimer.

(21) Appl. No.: **14/047,076**

(22) Filed: **Oct. 7, 2013**

(65) **Prior Publication Data**

US 2014/0029444 A1 Jan. 30, 2014

Related U.S. Application Data

(63) Continuation of application No. 12/769,095, filed on Apr. 28, 2010, now Pat. No. 8,599,793.

(51) **Int. Cl.**

H04W 24/08 (2009.01)
H04W 36/32 (2009.01)
H04W 24/00 (2009.01)
H04W 28/02 (2009.01)

(52) **U.S. Cl.**

CPC **H04W 24/00** (2013.01); **H04W 24/08** (2013.01); **H04W 28/02** (2013.01); **H04W 36/32** (2013.01)

(58) **Field of Classification Search**

None

See application file for complete search history.

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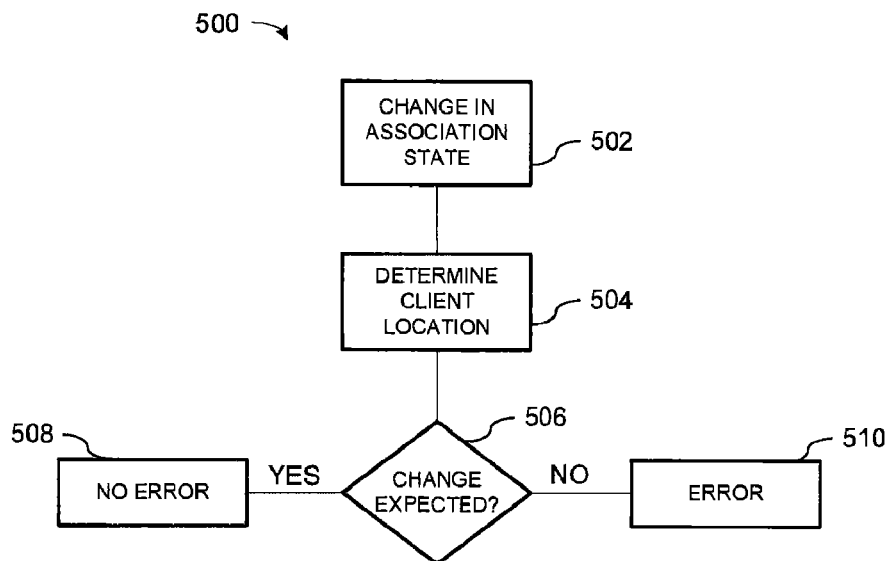
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(57) **ABSTRACT**

In an example embodiment, a service that analyzes location information of a client as the client roams. For example, whenever a trigger event occurs, such as a change in the association state, a change in Internet Protocol (IP) address, etc., a determination is made whether the event was expected. If the event was not expected, the location of where the trigger event occurred can be determined enabling a network administrator to investigate roaming problems at a particular location.

20 Claims, 3 Drawing Sheets



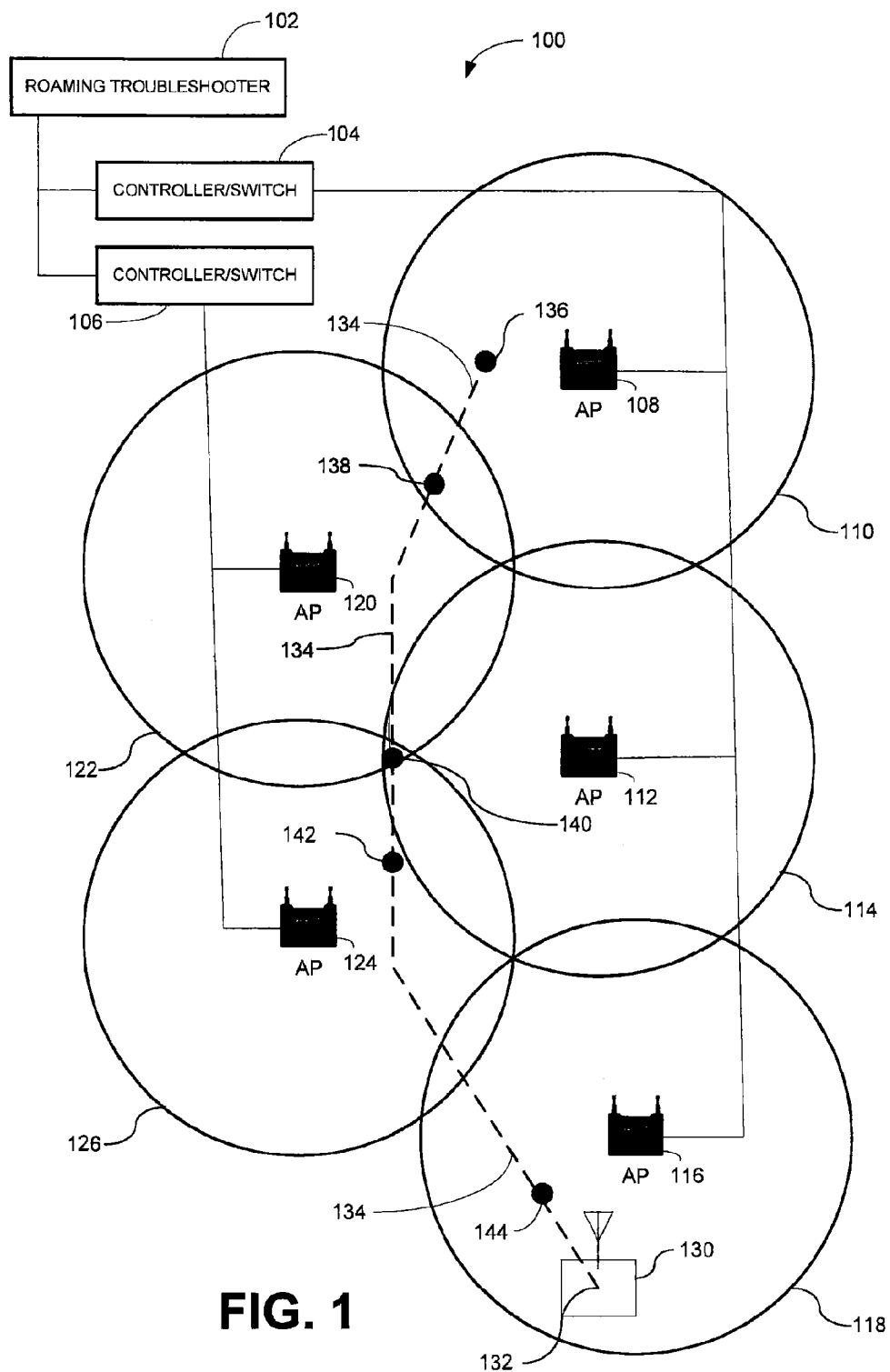


FIG. 1

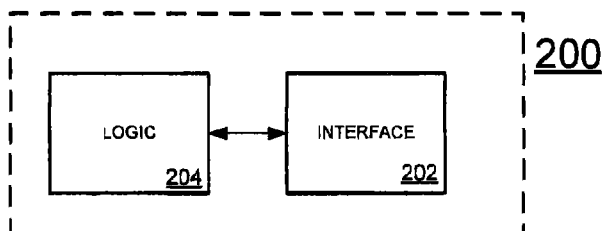


FIG. 2

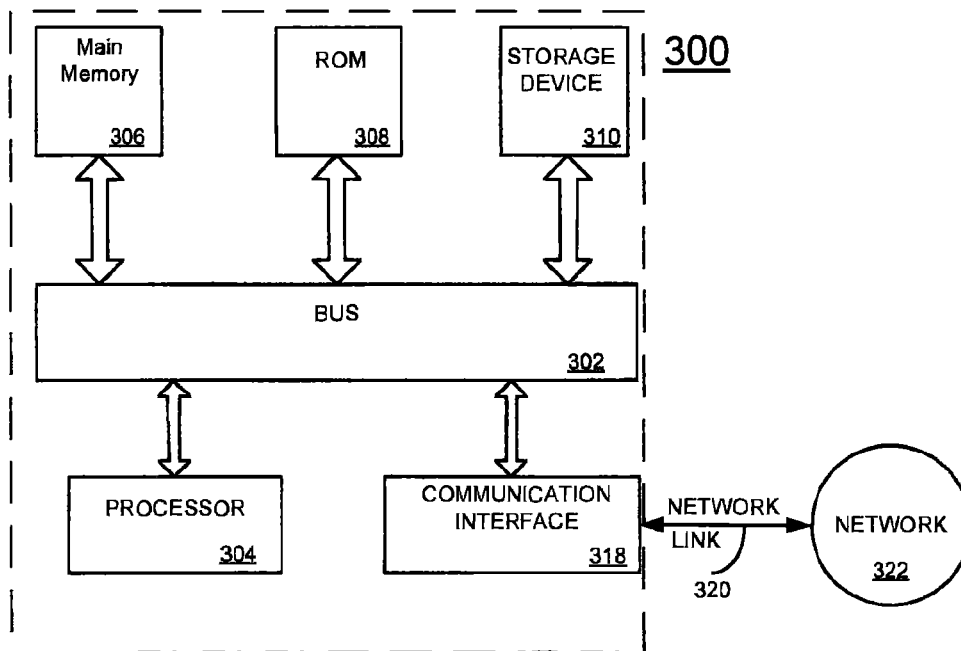
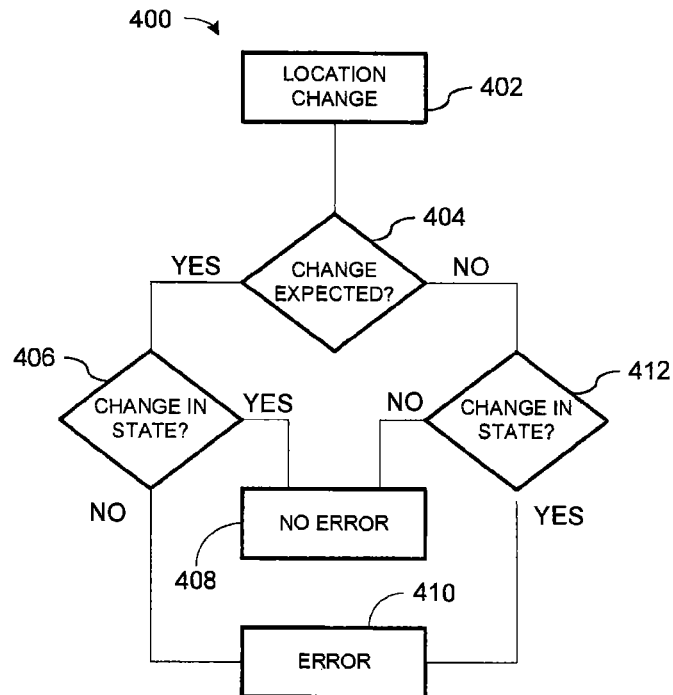
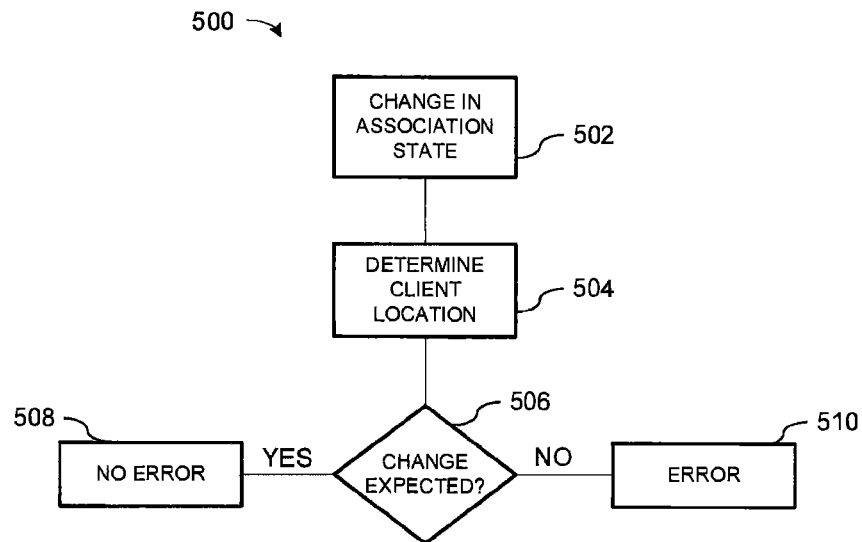


FIG. 3

**FIG. 4****FIG. 5**

1

TROUBLESHOOTING CLIENT ROAMING**CROSS REFERENCE TO RELATED APPLICATIONS**

This application is a continuation of U.S. patent application Ser. No. 12/769,095, filed on Apr. 28, 2010.

TECHNICAL FIELD

The present disclosure relates generally to client roaming.

BACKGROUND

A problem with many WiFi network environments is that client roaming across access points (APs) is sporadic. With the introduction of wireless networking environments where controller functionality is being split across the access edge network switch, client roaming problems are likely to be even more prevalent.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings incorporated herein and forming a part of the specification illustrate the examples embodiments.

FIG. 1 illustrates an example of a wireless network employing a roaming troubleshooter.

FIG. 2 illustrates an example block diagram of a roaming troubleshooter.

FIG. 3 illustrates an example of a computer system upon which an example embodiment may be implemented.

FIG. 4 illustrates an example of a methodology for analyzing roaming activity in response to movement by a wireless device.

FIG. 5 illustrates an example methodology for analyzing roaming activity in response to a change in association state by a wireless device.

OVERVIEW OF EXAMPLE EMBODIMENTS

The following presents a simplified overview of the example embodiments in order to provide a basic understanding of some aspects of the example embodiments. This overview is not an extensive overview of the example embodiments. It is intended to neither identify key or critical elements of the example embodiments nor delineate the scope of the appended claims. Its sole purpose is to present some concepts of the example embodiments in a simplified form as a prelude to the more detailed description that is presented later.

In accordance with an example embodiment, there is disclosed herein an apparatus configured for analyzing roaming activity in response to movement by a wireless device. The apparatus comprises an interface operable to receive data and logic coupled to the interface and operable to analyze the received data. The logic is operable to determine from received data whether a mobile device has changed location from a first location to a second location, and whether an association state for the mobile device should have changed while the mobile device moved to the second location.

In accordance with an example embodiment, there is disclosed herein a method for analyzing roaming activity in response to a change in association state by a wireless device. The method comprises determining an association state has changed for a mobile device, and determining a current location for the mobile device. The method determines whether

2

the association state should have changed based on the current location for the mobile device.

In accordance with an example embodiment, there is disclosed herein logic encoded in at least one tangible media and when executed by a processor operable to analyze roaming activity in response to a change in a wireless device's IP address. The logic determines that an Internet Protocol address for a mobile device changed. The logic determines a location where the Internet Protocol address for the mobile device changed. The logic correlates the location where the Internet Protocol address for the mobile device changed with known Internet Protocol assignment boundaries to determine whether the change in Internet Protocol address was expected.

DESCRIPTION OF EXAMPLE EMBODIMENTS

This description provides examples not intended to limit the scope of the appended claims. The figures generally indicate the features of the examples, where it is understood and appreciated that like reference numerals are used to refer to like elements. Reference in the specification to "one embodiment" or "an embodiment" or "an example embodiment" means that a particular feature, structure, or characteristic described is included in at least one embodiment described herein and does not imply that the feature, structure, or characteristic is present in all embodiments described herein.

In accordance with an example embodiment, there is described herein a new service, a "Roaming Troubleshooter" which can be instantiated on a Mobility Service Engine (MSE) that integrates with location services to automatically analyze mobile wireless device (client) roaming information and determine whether client roaming problems exist. Client roaming analysis data may be provided to external devices via any suitable means such as a (Simple Object Access Protocol/ Extensible Markup Language) SOAP/XML Application Program Interface (API).

In an example embodiment, the Roaming Troubleshooter is embodied in logic. "Logic", as used herein, includes but is not limited to hardware, firmware, software and/or combinations of each to perform a function(s) or an action(s), and/or to cause a function or action from another component. For example, based on a desired application or need, logic may include a software controlled microprocessor, discrete logic such as an application specific integrated circuit (ASIC), a programmable/programmed logic device, memory device containing instructions, or the like, or combinational logic embodied in hardware. Logic may also be fully embodied as software stored on a non-transitory, tangible medium which performs a described function when executed by a processor. Logic may suitably comprise one or more modules configured to perform one or more functions.

In an example embodiment, the Roaming Troubleshooter learns the positions of APs in an area. For example, the Roaming Troubleshooter may be pre-provisioned with location data for APs. The Roaming Troubleshooter determines the current attached controller for each AP through an AP monitoring service. The Roaming Troubleshooter also determines the (AAA (Authentication, Authorization, and Access) servers, SSIDs (service set identifiers), WLANs (wireless local area networks) and VLANs (virtual local area networks) currently configured on Controller/APs. This allows the Roaming Troubleshooting to determine a real time the mapping of networks and APs to controllers/switches.

In an example embodiment, as a client moves around an area, the Roaming Troubleshooter receives data from the controller and analyzes the physical location of the client as

well as the client's associated state (associated or not and to which AP), security profile and other information, as well as the client's (Internet Protocol) IP address, WLAN and VLAN.

In an example embodiment, there are three events that cause the Roaming Troubleshooter to perform further analysis:

- 1) The client's location has changed.
- 2) The client's associated state changed (for example roaming, the client disassociated and associated to the same AP, and/or other parameters related to the client's associated state changed such as security parameters).
- 3) The client's IP address changed or refreshed (e.g., went from assigned to 0.0.0.0 and back to assigned).

Upon detection of any of those events, the Roaming Troubleshooter looks up the current location of the client and/or determines the historical physical location trail for the client for a predetermined time period (for example in the last 1 hour). The roaming path starts for example at Point A and ends at Point B. This period could be configurable depending on mobility in the environment. By combining the physical location information with the event information listed below the Roaming Troubleshooter can show the affected areas of the network and which clients were affected by failed roam events.

In an example embodiment, the roaming troubleshooter can monitor data being provided to the client. For example, the roaming troubleshooter may be aware that the client is receiving a constant video stream, and as the client roams the troubleshooter could monitor statistics of the traffic to see at what point, if at any, the traffic stops temporarily, or changes to another access point, and then relate that event to a location.

In an example embodiment, the Roaming Troubleshooter determines whether the client lost association state while the moving across the roaming path. For roaming paths, the assumption is that a client should never lose association state with at least one AP in the mobility domain. If the client lost association state and then regained it, then the location system would record an event with the location area where they lost and regained association state, the physical location(s) of the device while they remained unassociated and where they gained it again. This record can then be queried using the SOAP/XML API or sent asynchronously to interested management systems to provide a zone of failure where roams are failing.

In an example embodiment, the Roaming Troubleshooter analyzes the roaming path to determine whether the client should have changed association state as the client moved around an area. For example, if the client roamed from one AP to another, what was the change (if any) of the client's physical location. An analysis can be performed to determine whether a roam was expected at the client's location. If a roam was not expected, then record a problem. If a client did not change location, this may indicate a potential problem that too much roaming is occurring. The Roaming Troubleshooter can record the roaming event. If the client's location did change, the Roaming Troubleshooter can determine whether the roam was expected based on AP coverage and the client's physical location at the time of the roam. If a roam was not expected, then the roam can be recorded as a roaming event that management systems can query or receive asynchronously.

In an example embodiment, the Roaming Troubleshooter analyzes the roaming path to determine whether the Internet Protocol (IP) address for the client should have changed as client moved on the roaming path. If the client IP address changed, the Roaming Troubleshooter determines the physi-

cal location where the occurred and correlates the location with IP assignment boundaries. The IP assignment boundaries can be determined based on the known configuration of APs, and therefore, controllers the client roamed across can be determined. The Roaming Troubleshooter knows which VLANs, WLANs AAA, servers, etc. are assigned to each controller, and is therefore able to determine if an IP address change was expected. In particular embodiments, the Roaming Troubleshooter would determine based on AP/Controller mappings at the time, which SSID was being used, which VLAN and which AAA server. If the IP address change (or refresh where a client gets a new IP address that was the same as before) that occurred was expected then no event record is recorded. If, however, the IP address change and/or refresh occurred was not expected, an event record is generated.

In an example embodiment, the Roaming Troubleshooter determines whether other devices may have been affected by lost association, roam events, or IP address changes at the same time and/or same (or a nearby) location as the originating device that cause the analysis trigger to fire. Combining the location data devices that had the same problem allows network managers to visualize the full impact of an error that may have cause the roam to occur at a particular location.

In an example embodiment, the Roaming Troubleshooter correlates the historical information of roam events over time for a physical location and/or area (such as a floor/conference room, and/or area within the floor) to determine whether roaming problems occur more often at particular locations. This analysis can be performed using aggregated client data or data for a particular client.

FIG. 1 illustrates an example of a wireless network employing a roaming troubleshooter **102**. In the illustrated example roaming troubleshooter **102** is coupled to a first controller and/or switch (controller/switch) **104** and a second controller/switch **106**. In an example embodiment, controller/switch **104** is associated with a first network and controller/switch **106** is associated with a second network.

In the illustrated example, controller/switch **104** is coupled to access point (AP) **108** with a coverage area illustrated by circle **110**, AP **112** with a coverage area illustrated by circle **114**, and AP **116** with a coverage area illustrated by circle **118**. Controller/switch **106** is coupled to AP **120** with a coverage area illustrated by circle **122**, and AP **124** with a coverage area illustrated by circle **126**.

For purposes of illustration, a wireless device **130** is illustrated at location **132**. For the examples described herein wireless device **130** traveled along path **134** although those skilled in the art should readily appreciate that wireless device **130** may travel any path. In this example, wireless device is associated with AP **108** at location **136**, AP **120** at location **138**, one of APs **112**, **120**, **124** at location **140**, AP **124** at location **142**, and AP **116** at location **134**.

The number of controllers/switches, access points, networks, and clients illustrated in the example of FIG. 1 were chosen for illustrative purposes only. Those skilled in the art should readily appreciate that the roaming troubleshooter **102** can perform the functionality described herein with networks suitably comprising any physically realizable number of networks, controllers/switches, access points, and clients.

In operation, roaming troubleshooter **102** is operable to determine from received data whether device **130** has changed location. Roaming Troubleshooter **102** is operable to determine from data received from either controller/switch **104** and/or controller/switch **106** whether an association state for the mobile device should have changed while the mobile device moved to the second location. For example, while mobile device **130** moves from location **136** to location **138**

5

the association state may not change; however, by the time mobile device **130** reaches location **140** the association state should have changed. If the association state has not changed this would indicate a roaming error has occurred. Roaming Troubleshooter **102** may log the error and/or transmit data representative of the error to another device (not shown).

In an example embodiment, roaming troubleshooter **102** is operable to determine from received data that the mobile device roamed from a first access point to a second access point, and is further operable to determine whether the association state for the mobile device should have changed based on whether data whether the second access point is appropriate for the second location.

For example, if while moving from location **136** to location **138** mobile device **130** changes association from AP **108** to AP **120**, roaming troubleshooter **102** can determine whether AP **120** is appropriate for location **138**. Since location **138** is within AP **120**'s coverage area **112**, the roam from AP **108** to AP **120** can be expected.

If, however, while moving from location **134** to location **138** mobile device **130** changes association from AP **108** to AP **112**, roaming troubleshooter **102** determines Since location **138** is outside of AP **112**'s coverage area **114**, and that while at location **138** mobile device **130** should be associated with either AP **108** or AP **120**. Therefore, roaming troubleshooter **102** determines a roaming error occurred. Roaming Troubleshooter **102** may log the error and/or transmit data representative of the error to another device (not shown).

In an example embodiment, roaming troubleshooter **102** is operable to determine from received data that mobile device **130** has remained associated with a first access point while moving from the first location and the second location. Roaming troubleshooter **102** determines whether the association state for the mobile device should have changed based on the change in location. For example, if while mobile device moves from location **142** to location **144** and remains associated with AP **124**, roaming troubleshooter **102** can determine that a roaming error occurred as mobile device **130** should be associated with AP **116** while at location **144**. Roaming Troubleshooter **102** may log the error and/or transmit data representative of the error to another device (not shown).

In an example embodiment, roaming troubleshooter **102** is operable to determine the association state for the mobile device should not have changed if the mobile device has not moved from a current location. For example, if while at location **142** mobile device **130** changes association from AP **124** to AP **120** (or any other of the APs **108**, **112**, **116** illustrated in the example), this would indicate a roaming error occurred. In particular embodiments, roaming troubleshooter **102** may determine a roaming error occurred even if mobile device **130** roamed while in the coverage area of the new AR. For example, if while at location **140** (which is within coverage area **122** of AP **120**, coverage area **114** of AP **112** and coverage area **126** of AP **124**) mobile device **130** is associated with AP **112**, and without moving changes association to either AP **120** or AP **112**, roaming troubleshooter **102** determines a roaming error occurred. Roaming Troubleshooter **102** may log the error and/or transmit data representative of the error to another device (not shown).

In an example embodiment, is responsive to receiving data indicating that an Internet Protocol (IP) address for mobile device **130** was changed or refreshed, to determine whether the change was appropriate based on mobile device **130**'s current location or based on the path mobile device **130** took from one location to the next. For example, roaming troubleshooter **102** upon detecting that the IP address for mobile

6

device **130** changed, determines that mobile device **130** moved along path **138** from location **142** to **144**. Because location **142** is within coverage area **126** of AP **124** which is associated with controller/switch **106** while location **144** is within coverage area **118** of AP **116** associated with controller **104**, the change in IP address can be expected. If for example, mobile device **130** changed or refreshed its IP address and while mobile device **130** moved from location **144** to location **132**, both of which are within coverage area **118** of AP **116**, roaming troubleshooter **102** can determine that a roaming error occurred. Roaming Troubleshooter **102** may log the error and/or transmit data representative of the error to another device (not shown). Alternatively, if while mobile device **130** moves from location **144** to location **132** the IP address of mobile device **130** does not change, roaming troubleshooter **102** determines that no roaming error occurred. However, if mobile device moves from location **142** to location **144** and the IP address does not change, roaming troubleshooter **102** determines a roaming error occurred. Roaming Troubleshooter **102** may log the error and/or transmit data representative of the error to another device (not shown).

In an example embodiment, roaming troubleshooter **102** is operable to correlate association state changes for a plurality of mobile devices by time. For example, if an unusual number of association state changes take place at a certain time, e.g. a particular time of day, roaming troubleshooter **102** can determine that there is a potential roaming problem. Roaming Troubleshooter **102** may log the error and/or transmit data representative of the error to another device (not shown).

In an example embodiment, roaming troubleshooter **102** is operable to correlate association state changes for a plurality of mobile devices by location. The correlation may be performed over a predetermined time period. If a particular location has an unusual number of roams during the predetermined time period, roaming troubleshooter **102** and determine that there is a potential roaming problem. Roaming Troubleshooter **102** may log the error and/or transmit data representative of the error to another device (not shown).

FIG. 2 illustrates an example block diagram of a roaming troubleshooter **200**. Roaming troubleshooter **200** is suitable for implementing the functionality of roaming troubleshooter **102** described supra in FIG. 1. Roaming troubleshooter **200** comprises an interface **202** and logic **204**. Interface **202** is suitable for receiving data from external devices such as switches/controllers, APs, etc. In particular embodiments, interface **202** is also operable to transmit data to external devices via a network. Logic **204** is operable to analyze the data received via interface **202** to determine whether roaming problems are being encountered.

For example, referring to FIG. 1 with continued reference to FIG. 2, logic **204** is operable to determine from data received via interface **202** whether device **130** has changed location. Logic **204** is operable to determine from data received from either controller/switch **104** and/or controller/switch **106** via interface **202** whether an association state for the mobile device should have changed while the mobile device moved to the second location. For example, while mobile device **130** moves from location **136** to location **138** the association state may not change; however, by the time mobile device **130** reaches location **140** the association state should have changed. If the association state has not changed this would indicate a roaming error has occurred. Logic **204** may log the error and/or transmit data representative of the error to another device (not shown).

In an example embodiment, logic **204** is operable to determine from data received via interface **202** that the mobile

device roamed from a first access point to a second access point, and is further operable to determine whether the association state for the mobile device should have changed based on whether data whether the second access point is appropriate for the second location.

For example, if while moving from location 134 to location 138 mobile device 130 changes association from AP 108 to AP 120, logic 204 can determine whether AP 120 is appropriate for location 138. Since location 138 is within AP 120's coverage area 112, the roam from AP 108 to AP 120 can be expected.

If, however, while moving from location 134 to location 138 mobile device 130 changes association from AP 108 to AP 112, logic 204 determines Since location 138 is outside of AP 112's coverage area 114, and that while at location 138 mobile device 130 should be associated with either AP 108 or AP 120. Therefore, logic 204 determines a roaming error occurred. Logic 204 may log the error and/or transmit via interface 202 data representative of the error to another device (not shown).

In an example embodiment, logic 204 is operable to determine from data received via interface 202 that mobile device 130 has remained associated with a first access point while moving from the first location and the second location. Logic 204 determines whether the association state for the mobile device should have changed based on the change in location. For example, if while mobile device moves from location 142 to location 144 and remains associated with AP 124, logic 204 can determine that a roaming error occurred as mobile device 130 should be associated with AP 116 while at location 144. Logic 204 may log the error and/or transmit via interface 202 data representative of the error to another device (not shown).

In an example embodiment, logic 204 is operable to determine the association state for the mobile device should not have changed if the mobile device has not moved from a current location. For example, if while at location 142 mobile device 130 changes association from AP 124 to AP 120 (or any other of the APs 108, 112, 116 illustrated in the example), this would indicate a roaming error occurred. In particular embodiments, logic 204 may determine a roaming error occurred even if mobile device 130 roamed while in the coverage area of the new AP. For example, if while at location 140 (which is within coverage area 122 of AP 120, coverage area 114 of AP 112 and coverage area 126 of AP 124) mobile device 130 is associated with AP 112, and without moving changes association to either AP 120 or AP 112, logic 204 determines a roaming error occurred. Logic 204 may log the error and/or transmit via interface 202 data representative of the error to another device (not shown).

In an example embodiment, logic 204 is responsive to receiving data via interface 202 indicating that an Internet Protocol (IP) address for mobile device 130 was changed or refreshed, to determine whether the change was appropriate based on mobile device 130's current location or based on the path mobile device 130 took from one location to the next. For example, logic 204 upon detecting that the IP address for mobile device 130 changed, determines that mobile device 130 moved along path 138 from location 142 to 144. Because location 142 is within coverage area 126 of AP 124 which is associated with controller/switch 106 while location 144 is within coverage area 118 of AP 116 associated with controller 104, the change in IP address can be expected. If for example, mobile device 130 changed or refreshed its IP address and while mobile device 130 moved from location 144 to location 132, both of which are within coverage area 118 of AP 116, logic 204 can determine that a roaming error occurred. Logic 204 may log the error and/or transmit data representative of

the error to another device (not shown). Alternatively, if while mobile device 130 moves from location 144 to location 132 the IP address of mobile device 130 does not change, logic 204 determines that no roaming error occurred. However, if mobile device moves from location 142 to location 144 and the IP address does not change, logic 204 determines a roaming error occurred. Logic 204 may log the error and/or transmit via interface 202 data representative of the error to another device (not shown).

In an example embodiment, logic 204 is operable to correlate association state changes for a plurality of mobile devices by time. For example, if an unusual number of association state changes take place at a certain time, e.g. a particular time of day, logic 204 can determine that there is a potential roaming problem. Logic 204 may log the error and/or transmit via interface 202 data representative of the error to another device (not shown).

In an example embodiment, logic 204 is operable to correlate association state changes for a plurality of mobile devices by location. The correlation may be performed over a predetermined time period. If a particular location has an unusual number of roams during the predetermined time period, logic 204 can determine that there is a potential roaming problem. Logic 204 may log the error and/or transmit via interface 202 data representative of the error to another device (not shown).

FIG. 3 illustrates an example of a computer system 300 upon which an example embodiment may be implemented. For example, computer system 300 may be employed to implement the functionality of roaming troubleshooter 102 (FIG. 1) or logic 204 (FIG. 2).

Computer system 300 includes a bus 302 or other communication mechanism for communicating information and a processor 304 coupled with bus 302 for processing information. Computer system 300 also includes a main memory 306, such as random access memory (RAM) or other dynamic storage device coupled to bus 302 for storing information and instructions to be executed by processor 304. Main memory 306 also may be used for storing a temporary variable or other intermediate information during execution of instructions to be executed by processor 304. Computer system 300 further includes a read only memory (ROM) 308 or other static storage device coupled to bus 302 for storing static information and instructions for processor 304. A storage device 310, such as a magnetic disk or optical disk, is provided and coupled to bus 302 for storing information and instructions.

An aspect of the example embodiment is related to the use of computer system 300 for troubleshooting mobile device roaming. According to an example embodiment, troubleshooting mobile device roaming is provided by computer system 300 in response to processor 304 executing one or more sequences of one or more instructions contained in main memory 306. Such instructions may be read into main memory 306 from another computer-readable medium, such as storage device 310.

Execution of the sequence of instructions contained in main memory 306 causes processor 304 to perform the process steps described herein. One or more processors in a multi-processing arrangement may also be employed to execute the sequences of instructions contained in main memory 306. In alternative embodiments, hard-wired circuitry may be used in place of or in combination with software instructions to implement an example embodiment. Thus, embodiments described herein are not limited to any specific combination of hardware circuitry and software.

The term "computer-readable medium" as used herein refers to any medium that participates in providing instruc-

tions to processor 304 for execution. Such a medium may take many forms, including but not limited to non-volatile media, and volatile media. Non-volatile media include for example optical or magnetic disks, such as storage device 310. Volatile media include dynamic memory such as main memory 306. As used herein, tangible media may include volatile and non-volatile media. Common forms of computer-readable media include for example floppy disk, a flexible disk, hard disk, magnetic cards, paper tape, any other physical medium with patterns of holes, a RAM, a PROM, an EPROM, a FLASHPROM, CD, DVD or any other memory chip or cartridge, or any other medium from which a computer can read.

Computer system 300 also includes a communication interface 318 coupled to bus 302. Communication interface 318 provides a two-way data communication coupling computer system 300 to a network link 320 that is connected to network 322. This allows computer system 300 to acquire data from external devices such as controllers/switches, APs, etc. For example, communication interface 318 may be a local area network (LAN) card to provide a data communication connection to a compatible LAN. As another example, communication interface 318 may be an integrated services digital network (ISDN) card or a modem to provide a data communication connection to a corresponding type of telephone line. Wireless links may also be implemented. In any such implementation, communication interface 318 sends and receives electrical, electromagnetic, or optical signals that carry digital data streams representing various types of information.

Computer system 300 can send messages and receive data, including program codes, through the network(s), network link 320, and communication interface 318. In accordance with an example embodiment, a downloaded application provides the program code for troubleshooting mobile device roaming as described herein.

In view of the foregoing structural and functional features described above, methodologies in accordance with example embodiments will be better appreciated with reference to FIGS. 4 and 5. While, for purposes of simplicity of explanation, the methodologies of FIGS. 4 and 5 are shown and described as executing serially, it is to be understood and appreciated that the example embodiments are not limited by the illustrated orders, as some aspects could occur in different orders and/or concurrently with other aspects from that shown and described herein. Moreover, not all illustrated features may be required to implement the methodologies described herein. The methodologies described herein are suitably adapted to be implemented in hardware, software, or a combination thereof.

FIG. 4 illustrates an example of a methodology 400 for analyzing roaming activity in response to movement by a wireless device. Methodology 400 may be implemented by roaming troubleshooter 102 (FIG. 1), logic 204 (FIG. 2) and/or computer system 300 (FIG. 3).

At 402, a location change for a mobile device is determined. The change may be detected based on data received from an access point, controller, switch, etc. At 404, an inquiry is made to determine whether an association state change was expected. State changes may include, but are not limited to, a change in the associated AP and/or IP address of the mobile device.

If, at 404, an association state change was expected (YES), at 406 a determination is made whether the association state changed. If the association state changed, and in particular embodiments whether the change was correct, e.g., to an appropriate AP or an appropriate IP address, (YES), the roam was expected and no error is detected as indicated at 408. If,

however, at 406, a determination is made that no change was made when a change was expected, or in particular embodiments the change was not correct, e.g., to the wrong AP or an incorrect IP address, (NO), at 406 an error condition is determined as indicated at 410. In an example embodiment, a log entry of the error is generated and/or a message with data representative of the error condition is transmitted.

If, at 404, a change in the association state was not expected (NO), at 412 a determination is made whether there was a change in state. If, at 412, a determination is made that no change in association state occurred (NO), then no error is detected as indicated by 408. If, however, at 412, a determination was made that the association state changed (when a change was not expected as referenced at 404)(NO), an error condition is indicated at 410. In an example embodiment, a log entry of the error is generated and/or a message with data representative of the error condition is transmitted.

FIG. 5 illustrates an example methodology 500 for analyzing roaming activity in response to a change in association state by a wireless device. Methodology 500 may be implemented by roaming troubleshooter 102 (FIG. 1), logic 204 (FIG. 2) and/or computer system 300 (FIG. 3).

At 502, a change in the association state of a mobile device is determined. Any number of techniques may be employed to determine a change in the association state. For example, a change in the association state may be determined by determining a mobile device lost association and/or re-associated, roamed to a new access point, disassociated and re-associated with the same access point and/or changed or refreshed its IP address.

At 504, the location of the mobile device is determined. In an example embodiment, the path or known locations that a mobile device traveled over a predetermined time period is also determined. For example, if a mobile device lost association and later re-associated the locations where association was lost and where re-association occurred are determined.

At 506, a determination is made whether the change in association state was expected. For example, if the mobile device lost association, a determination is made whether lost association was expected because the device was no longer within a coverage area provided by the network. As another example, if a mobile device roamed from a first AP to a second AP, a determination is made whether the mobile device should have remained associated with the first AP. Still another example, if a mobile device roamed from a first AP to a second AP, did the mobile device move to a new location. Yet another example, if a mobile device changed or refreshed its IP address, a determination may be made whether the IP address should have changed or been refreshed based on the location or path taken by the mobile device.

If at 506 the change in association state was expected (YES), no error is detected as indicated by 508. If, however, at 506 the change in association state was not expected (NO), an error condition is determined as indicated by 510. A log entry may be generated and/or a message with data representative of the error condition is transmitted.

Described above are example embodiments. It is, of course, not possible to describe every conceivable combination of components or methodologies, but one of ordinary skill in the art will recognize that many further combinations and permutations of the example embodiments are possible. Accordingly, this application is intended to embrace all such alterations, modifications and variations that fall within the spirit and scope of the appended claims interpreted in accordance with the breadth to which they are fairly, legally and equitably entitled.

11

The invention claimed is:

1. An apparatus, comprising:

an interface operable to receive data; and

logic coupled with the interface and operable to analyze the received data;

wherein the logic is operable to determine from the received data whether an associated mobile device has changed location from a first location to a second location in accordance with a changed Internet Protocol address associated with the associated mobile device;

wherein the logic is further operable to determine (i) a change in an association state for the associated mobile device while the associated mobile device moved from the first location to the second location and (ii) whether the change in the association state was expected.

2. The apparatus set forth in claim 1, wherein:

the logic is operable to determine from the received data that the associated mobile device roamed from a first access point to a second access point; and

the logic is further operable to determine whether the change in the association state for the associated mobile device was expected based on whether the second access point is appropriate for the second location.

3. The apparatus set forth in claim 2, wherein:

the interface is further operable to transmit data; and the logic is operable to transmit, via the interface, data indicating an error condition occurred responsive to determining the second access point is inappropriate for the second location.

4. The apparatus set forth in claim 1, wherein:

the logic is operable to determine from the received data that the associated mobile device has remained associated with a first access point while moving from the first location and the second location.

5. The apparatus set forth in claim 4, wherein:

the interface is further operable to transmit data; and the logic is operable to transmit, via the interface, data indicating an error condition occurred responsive to determining the mobile device should have roamed to a second access point while moving to the second location.

6. The apparatus set forth in claim 1, wherein the logic is further operable to determine the change in the association state for the associated mobile device is unexpected responsive to determining the associated mobile device has not moved from a current location.

7. The apparatus set forth in claim 1, wherein:

the logic is further operable to determine whether the change in the association state for the associated mobile device was expected based on determining an Internet Protocol address for the associated mobile device changed; and

the logic is further operable to determine from received data whether a change in the Internet Protocol address was expected while moving to the second location.

8. The apparatus set forth in claim 7, wherein:

the interface is further operable to transmit data; and the logic is operable to transmit, via the interface, data indicating an error condition occurred responsive to determining the change in the Internet Protocol address was unexpected while moving to the second location.

9. The apparatus set forth in claim 1, wherein the logic determines that an Internet Protocol address for the associated mobile device has not changed while moving to the second location; and wherein the logic is further operable to determine whether the Internet Protocol address should have remained unchanged while moving to the second location.

12

10. The apparatus set forth in claim 9, wherein the interface is further operable to transmit data; wherein the logic is operable to transmit data via the interface indicating an error condition occurred responsive to determining the Internet Protocol address for the associated mobile device should have remained unchanged while moving to the second location.

11. The apparatus set forth in claim 1, wherein the logic is operable to correlate association state changes for a plurality of associated mobile devices at the same time.

12. The apparatus set forth in claim 1, wherein the logic is operable to correlate association state changes for a plurality of associated mobile devices at a common location.

13. The apparatus according to claim 1, wherein the logic is operable to correlate roam events for a particular location over a time period to determine whether roaming errors are occurring at the particular location.

14. A method, comprising:

determining a change in an association state for a mobile device;

determining a current location for the mobile device;

determining a change in an Internet Protocol address of the mobile device; and

selectively determining, in accordance with the change in the Internet Protocol address of the mobile device, whether the change in the association state was expected based on the current location for the mobile device.

15. The method according to claim 14, wherein the determining the change in the association state for the mobile device comprises:

determining a first location where the mobile device lost association; and

determining a second location where the mobile device re-associated.

16. The method according to claim 14, wherein:

the determining the change in the association state comprises determining the mobile device has roamed to a new access point; and

the determining the change in the association state was expected comprises determining whether the roam was expected.

17. The method according to claim 14, wherein an association state is determined to have occurred responsive to the mobile device disassociating and re-associating with a same access point.

18. The method according to claim 14, further comprising: determining whether a first location for the mobile device has changed;

determining the change in the association state comprises determining that the association state should not have changed responsive to determining that the mobile device roamed from a first access point to a second access point and determining that the location of the first mobile device did not change.

19. Logic encoded in at least one non-transitory media for execution and when executed operable to:

receive data from an associated interface;

analyze the received data;

determine from the received data whether a mobile device has changed location from a first location to a second location in accordance with a changed Internet Protocol address associated therewith; and

determine (i) a change in an association state for the mobile device while the mobile device moved from the first location to the second location and (ii) whether the change in the association state was expected.

13

20. The logic of claim **19**, wherein the logic determines that the Internet Protocol address for the mobile device has changed responsive to determining the Internet Protocol address was refreshed.

* * * * *

5

14

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 9,148,797 B2
APPLICATION NO. : 14/047076
DATED : September 29, 2015
INVENTOR(S) : Allan Thomson

Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Specification:


In Description of the Example Embodiments:

Column 5, Line 52, please delete "AR" and insert --AP-- therefor;

In the Claims:

Column 12, Claim 18, Line 54, please delete "location of the first" and insert --first location of the-- therefor.

Signed and Sealed this
Twenty-eighth Day of June, 2016



Michelle K. Lee
Director of the United States Patent and Trademark Office